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ABSTRACT

This booklet on ecosystems considers time, space, and spirit. Time refers to a sense of history; space refers to geography; and spirit refers to life and thought. Several chapters on the history and concepts of ecology, a time line related to the concepts, a map of the important geography related to these concepts, a glossary of important terms, and a list of several study suggestions are included. (CW)

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Ecosystems

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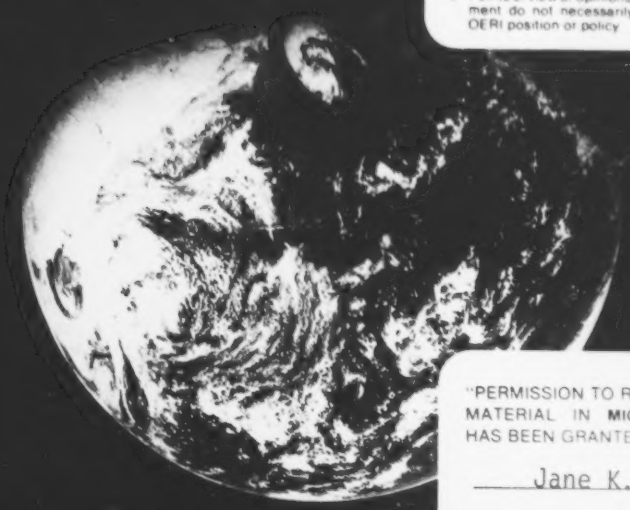

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A HAWKHILL LEARNING POWER BOOK

2

TIME, SPACE AND SPIRIT

KEYS TO SCIENTIFIC LITERACY

To the student,

This short book will help you understand our modern world. It has changed a lot since your parents were born. Even more since you were born. And it will change still more–much more–in your lifetime.

What is behind most of these big changes? Two things. Science and technology.

What can you do about it? The first step is to understand more about science and technology and how they connect with our world. Especially the ever-growing world of free democratic societies. One way to do this–the way this book follows–is to look at the world from three angles: *Time, Space* and *Spirit*.

Time means history. You can learn how science and technology have worked in the past and are working today.

Space means geography. You can learn where important things happened in the past and are happening today.

Spirit means life. The life of the mind. You can learn the key words, concepts and ideas that power science and technology (and society) today.

This book teaches about science, technology and society from all three of these angles–*Time, Space* and *Spirit*.

Read on.

This book belongs to:

Ecosystems

Bill Stonebarger
Illustrations by Lin Haley

Hawkhill Associates
Madison, Wisconsin

This book is one of a series of sixteen Learning Power Books in the *Time, Space and Spirit–Keys to Scientific Literacy* series. It is designed to accompany the video program of the same name.

The *Time, Space and Spirit–Keys to Scientific Literacy* series was written and produced with consultation from the History of Science Department at the University of Wisconsin-Madison.

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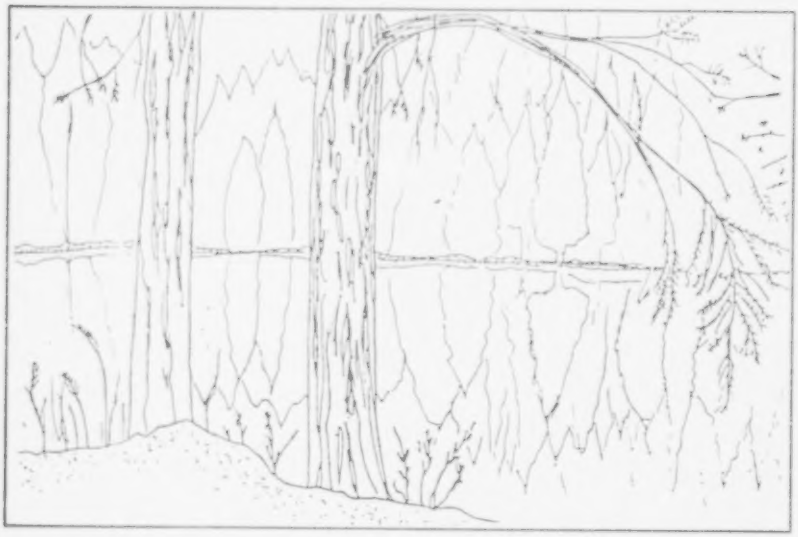
Part 1: From Nature Study to Ecology



Walden Pond

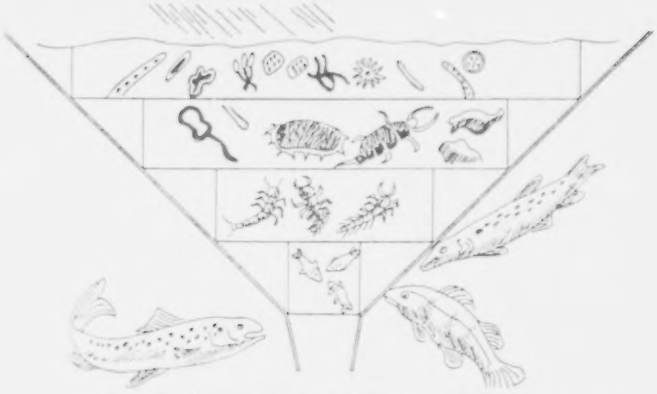
"We can never get enough of nature ... We need the tonic of wildness–to wade in marshes where the bittern and the meadow-hen lurk, and hear the booming of the snipe; to smell the whispering sedge where only some wilder and more solitary fowl builds her nest, and the mink crawls with its belly close to the ground."

Henry David Thoreau

So wrote Henry David Thoreau, writer, pencil-maker and self appointed inspector of snow-storms. He wrote these lines in a cabin he built himself for $28.12 1/2 at Walden Pond near Concord, Massachusetts in 1845.

Silver Springs, Florida

"Silver Springs is a thermostatic, chemostatic, and biostatic ecological community in seasonally puls-



ing steady state climax. The rate of primary production of the whole community is linearly proportional to the light intensity under natural conditions. The efficiency of primary production relative to incoming light of usable wavelengths reaching plant level is about 5.3 percent."

Howard Odum, ecologist

So wrote Howard T. Odum, professor, author and pioneer ecologist, describing a pond in Florida in 1957. He wrote these lines as a part of a scientific study published in a technical journal.

"to front only the essential facts of life"

For Thoreau the most important thing was to go "to the woods to front only the essential facts of life." To "spend one day as deliberately as nature, and not be thrown off the track by every nutshell and mosquito's wing that falls on the rails ... to stand right fronting face to face to a fact, and see the sun glimmer on both its surfaces, as if it were a cimeter, and feel its sweet edge dividing you through the heart and marrow."

to live in harmony with nature

In other words, to live in nature and with nature and not set oneself above nature. We should, Thoreau advised, learn nature's secrets not in order to conquer her or to exploit her resources. Instead we should learn to live in harmony with nature and, indeed, to unite with nature in a kind of emotional and spiritual union.

to control the environment

For Odum, on the other hand, the important thing was to understand the workings of nature so that we could better predict what would happen if we changed things.

For instance, what would happen if we changed the energy input; if we modified the food chains; if we changed the abiotic base; if some toxic waste entered the web. How could we improve the productivity of pond, farm or forest. In other words, the goal was a scientific understanding of nature so that we humans could better control nature for our own human purposes.

roots of ecology

Both of these approaches to the natural world have long histories. Only very recently have they come together to help form the modern science of ecology and to spark the environmental movements of the past few decades.

naturalist tradition

The tradition Thoreau represents is sometimes called the naturalist tradition. Its roots go back to early Greek and Roman civilizations. Thoreau himself was fond of quoting Homer, Cicero, Virgil, Pliny and other classical writers as authorities for what he called a "noble, clear-sighted way of life."

This was and is an approach to nature that lays great stress on direct experience, on minimal interference in the great cycles of nature, on wilderness and the purity of unsullied natural things. It is a

tradition that has much in common with some Eastern religions like Buddhism, Hinduism and Taoism.

Francis Bacon and control of nature

Though individuals often mixed them together, the historical tradition that Odum grew from was different from that of Thoreau. In earlier times it was most openly stated by the philosopher Francis Bacon in sixteenth century England. Bacon was not much interested in a humble reverence for nature. He wanted to dominate her. To understand and then to use nature for human purposes. "The enlargement of the bounds of Human Empire [note the capital H and E] to the effecting of all things possible," wrote Bacon. "The world is made for man, not man for the world."

western religious traditions

Some scholars point out that Bacon, one of the early pioneers in scientific philosophy, took his basic approach to nature directly out of the Jewish, Christian and Moslem religious traditions of the western world. God created the heavens and the earth to be good and fruitful, says the Bible, and he placed Adam and Eve on earth to take charge. "To have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth."

Charles Darwin

At about the same time Henry David Thoreau was building his cabin at Walden Pond, another naturalist across the ocean was strolling down a path every noon at his country home in Down,

England. He was putting together ideas that would shock the scientific and the social world of his day–and of ours. His name was Charles Darwin.

a naturalist and a scientist

Darwin, like Thoreau, was fascinated by nature. He began, as many naturalists have always begun, by observing nature. And by making collections of beetles, butterflies and other plants and animals near his home.

why? when? where? how?

But Darwin went a step further. He wondered. He asked himself questions. Why are there so many different kinds of plants and animals? How did each plant and animal get to be the way it is today? How is one plant or animal related to the other plants and animals living around it? And to the physical environment–the rocks, the water, the soil, the climate?

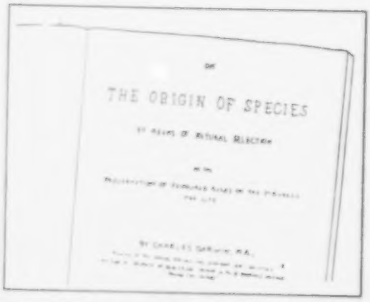
HMS Beagle

When Darwin got a chance to go on a voyage of exploration around the world as an unpaid naturalist, he snapped up the opportunity. At ev-

ery stop on the five-year-long voyage of HMS Beagle, Darwin would go ashore and explore the local geology and the living communities of plants and animals he found there.

a revolutionary book

Back home in England he settled in a quiet country home outside London to study and eventually to write a famous, revolutionary book, *On The Origin of Species by Means of Natural Selection*. In this book Darwin pulled together his observations with those of other naturalists and geologists. More important, he explained them with a new theory of evolution. This new theory laid basic foundations for all of biology, as well as for the yet-to-be-born science of ecology.


THE ORIGIN OF SPECIES

a complex web of life

"Nature," said Darwin, "is a web of complex relations" in which each organism plays a role. Ecologists today call this an ecosystem with niches.

struggle for existence

"All organic beings," wrote Darwin, "are striving to seize on each place in the economy of nature." In other words there is a "struggle for existence" in all these ecosystems.

All living things produce more offspring than can survive. There is always a variation in traits in offspring. Which will survive?

natural selection

The fittest, says Darwin. "The merest trifle would often give the victory to one organic being over another." Thus nature selects who will survive. Through this process of natural selection, given enough time, whole new species will be created.

controversy over natural selection

Darwin's ideas were controversial in his own day, as they are in ours. The vast majority of modern biologists, however, accept and use the framework that Darwin provided to help make sense of their own investigations into natural living systems today.

ecology becomes popular

Of all the specialized sciences gathered together under the general term "biology," the science of ecology, more than any other, builds on the insights Darwin provided. It was only in our own twentieth century, however, that ecology came to be a science in its own right. And only in the last twenty-five years that it has burst upon the public scene with such dramatic impact.

spaceship earth

Some think this vastly increased public awareness grew directly out of the first photographs taken of our planet earth from outer space. Here, at last, the idea of Darwin and others in the nineteenth century–that nature is a complex web of relationships colonizing a remarkably live planet–was obvious to everyone on earth. Get down to the de-

tails, however, and you run into hornet nests of controversy.

ecosystems

Professional ecologists like Howard Odum began to learn some of the secrets of these living webs of life when they did field studies of ecosystems in the 1950s. One of the most influential was Odum's study of a pond at Silver Springs, Florida.

need to measure in numbers

Unlike Thoreau, Odum and his students did more than observe with the unaided senses. They brought in all the sophisticated technology of modern science that they could find or invent. They were especially interested in quantitative studies–that is, measuring things in numbers. It wasn't enough to see the "sunlight glimmer on the silvery surface." They wanted to know exactly how much solar energy the pond received in kilocalories. They wanted to know how much of that energy was taken up by the producers, the green plants. And how much was taken by the consumers, plants and animals. They wanted to know in quantitative detail what the relationships were between each bird, snail, fish and water plant.

quantitative science

From their measurements they constructed detailed flow charts, not unlike factory organization charts, to trace what happened to the energy and matter in the living ecosystem. They published their findings in scientific journals, complete with charts, graphs and footnotes.

nature, environment and science

At the same time, naturalists, poets, backpackers and wilderness lovers used some of the new scientific knowledge about natural systems to enjoy and promote nature in much the same holistic, spiritual way that Thoreau had done in the last century. Some of the nature enthusiasts in the 1950s and 1960s went further. In taking up environmental banners for natural foods, natural cures, natural balances, some came to look on science and technology as suspect, if not downright evil. The possibility of human progress led by science and reason was sharply challenged.

wilderness in 19th century America

Although there were a few dissenters like Thoreau, William Burroughs and John Jacob Audubon, the general attitude of scientists as well as ordinary citizens in nineteenth century America was anti-wilderness. President Thomas Jefferson sent Lewis and Clark to explore the vast American wilderness in 1804-1806. They were directed to observe and record what they found. It was also clear that they were to be the vanguard of a nation intent on conquering the wilderness. This was the beginning of what would later be called our "manifest destiny" to create a great civilized nation from ocean to ocean.

natural resources for growing nation

New knowledge of nature's web of relationships served to encourage practical farmers, lumbermen, wildlife managers and engineers of all kinds to more effective efforts to manage that web. They wanted nature to produce more food, more lumber, more hunting and fishing opportunities and more energy and natural resources for a growing nation.

first national parks and forests

In order to assure the continued bounty of nature in this sense, conservation movements began. President Theodore Roosevelt, a big-game hunter himself, led the way. National parks and national forests were established. Laws governing hunting and fishing were passed and enforced.

Aldo Leopold

One of the most interesting and significant of the scientists who bridged the gap between the Thoreau-inspired whole-nature approach and the Darwin-grounded scientific approach was a wildlife expert named Aldo Leopold. Leopold began his career in this Theodore Roosevelt conservation tradition. In 1924 he became assistant

director of the U.S. Forest Products Laboratory in Madison, Wisconsin. By that time he was already beginning to question and to move away from some parts of the conservation ethic. He soon came to denounce, for instance, the ruthless extermination of predators in America. He also began to question the whole idea of human progress as a technological juggernaut that was harming nature and man.

"land is a community"

In a cabin in the sand country along the Wisconsin River he wrote a classic book, *Sand County Almanac.* In this book he gave his maturing views about nature, man and science. "Conservation is getting nowhere," wrote Leopold, "because it is incompatible with our Abrahamic concept of land. We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect. That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics."

Rachel Carson and *Silent Spring*

In 1962 the biologist Rachel Carson, carried these ideas a step further in a famous book, *Silent Spring*. In this book she warned that unless we changed our ways and cut back drastically on modern toxic chemical pollution we would end up destroying the very biosphere we all depend upon for our life. Carson's book was read by millions of people, and more than any other single book, had great influence on the environmental movements today.

Read on to Part 2 to learn some of the fundamental concepts of ecology today. And of the controversies.

Part 2: The Web of Life

"As I sit at my window ..."

"As I sit at my window this summer afternoon, hawks are circling about my clearing; the tantivy of wild pigeons gives a voice to the air; a fish hawk dimples the glassy surface of the pond and brings up a fish; a mink steals out of the marsh before my door and seizes a frog by the shore; and for the last half-hour I have heard the rattle of railroad cars, now dying away and then reviving like the beat of a partridge, conveying travelers from Boston to the country."

So Henry David Thoreau described Walden Pond in 1847. A modern ecologist would see and hear some of the same things, but describe them in a different way. Let's take a look at the modern ecological approach to nature.

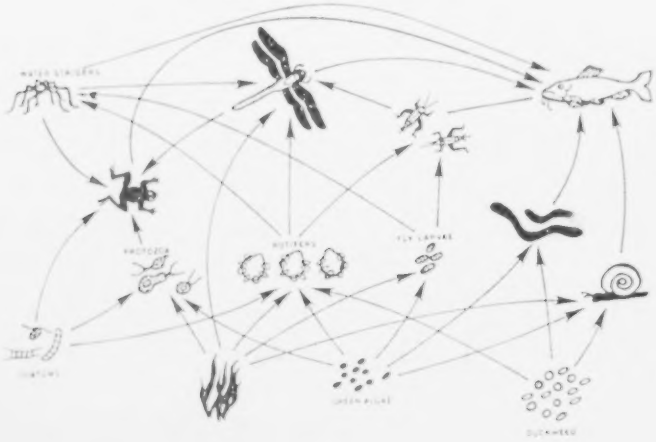
what is ecology?

First, what is ecology? The word "ecology" comes from a Greek word meaning "at home," or "places to live." Ecology is a branch of the broader field of

biology. It is the branch that studies living creatures in their environment. Living creatures at home. Another way of putting it–ecologists study organisms in the totality of their relationships one to another, and to the physical environment in which they live.

ecosystems

That's quite a mouthful. Let's take Walden Pond, for example. To the ecologist Walden Pond is an example of an ecosystem. That is, a complex web of relationships of living things and their environment that can best be described in graphic and quantitative ways.



energy flow in ecosystems

At the most basic level we have energy. The relationships between the hawks and the pigeons, the pigeons and the pine boughs, the mink and the frogs and, not least, the human and the railroad cars can all be usefully described in terms of energy flow.

laws of thermodynamics

The physicist must enter here. To understand energy in ecosystems you must first understand two basic laws of energy. One is the first law of thermodynamics. This says that energy can be changed from one form to another, but energy can

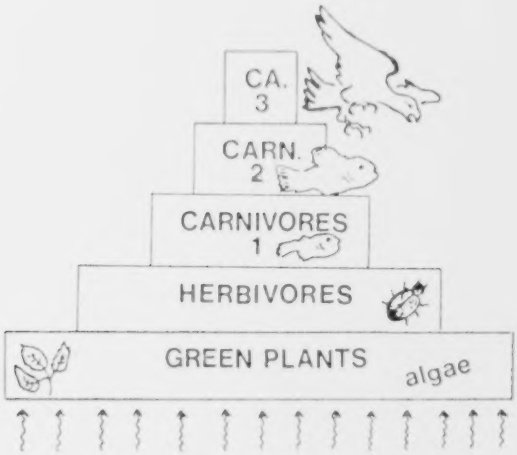
never be created or destroyed. This first law is sometimes called the law of conservation of energy.

energy moves "downhill"

The second law of thermodynamics points out that while you cannot create or destroy energy, energy is always moving "downhill" in its changes. That is, in every energy change you always lose something. And that lost something is energy as random heat, useful only for warming the universe. Another way to put this–there is no such thing as a perpetual motion machine. You never get as much work out of a machine as you put in.

energy pyramids

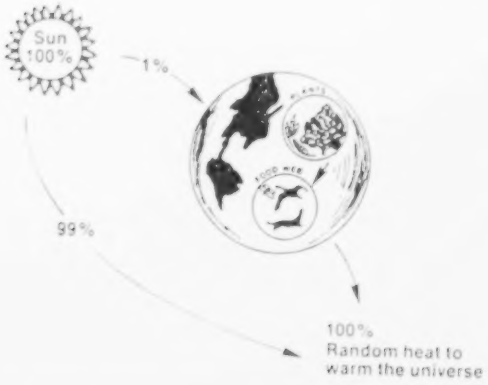
As for Walden Pond, it is the sun that provides the basic high-quality energy at the bottom of the energy pyramid. Ecologists can measure with a good deal of precision exactly how many kilocalories of solar energy the pond receives in a given day, week, month or year. Ecologists have a name for organisms that can use that sunlight energy directly to power their own life activities. They are



called producers. In the pond ecosystem the producers are the pondweeds, algae and other green plants that are able to use sunlight as a source of energy to produce food. The plants do this using a process is called photosynthesis.

producer plants

It turns out that careful measurements have shown that, on the average, green producer plants are able to use only a small percentage of the sunlight that arrives each day. From one to five percent, depending on the particular plant and ecosystem. This means that about ninety-five percent or more of the incoming energy is sent back to the air, the water and the surrounding earth. Eventually this energy–heat energy now–is radiated back out to space. Warming the universe.

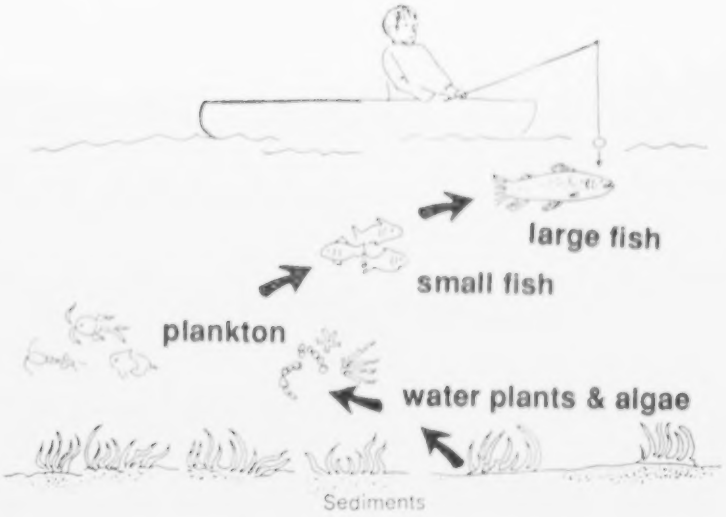


consumers

The producer plants use some of that manufactured food–concentrated sunlight you might call it–for their own growth and life activities. Most of the plant food, however, is eaten by the consumers. In ecosystem terminology, the consumers are living things–animals primarily–that convert the plant-produced food energy into new kinds of living structures and new kinds of living activities. Structures like eyes and ears, legs and wings, claws and brains. Activities like walking and swimming, eating and thinking.

food chains

In the case of Walden Pond, the consumers are the hawks, the pigeons, the fish, the frogs, the microscopic water plants and in his day, Henry David Thoreau. Each consumer may be only one link in what is called a food chain.



efficiency of consumers

The producers, we pointed out, are able to use only a few percent of the incoming sunlight energy. The consumers, it turns out, can do a little better in efficiency. They can convert about ten percent of the producer food into consumer life energy.

decomposers

There is one more class of organisms that live at and in Walden Pond and perform an essential function in that ecosystem. These organisms are by far the most numerous and few people even know they exist. They are what ecologists call decomposers. In the water itself, and especially on the bottom of the pond, there live billions on billions of bacteria, molds and other microscopic organisms that are able to decompose the dead plants and animals, as well as the wastes from living plants and animals. In that process they are

able to use what remains of the locked-up sun energy of the producers and consumers for their own growth, reproduction and survival.

energy is lost

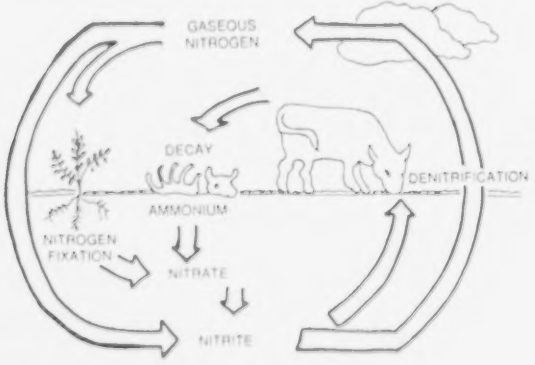
After the decomposers are through, all of the originally captured sun energy has been used–and lost. Not destroyed, mind you, but lost. Unavailable anymore for any useful purpose. Sent back out to space to warm the universe.

recycling of matter

Energy flow is only one way ecologists have for looking at a given ecosystem. You can also do a detailed study of the way matter circulates within the ecosystem. Like energy, matter too can neither be created nor destroyed. From the matter point of view, life is built of twenty to thirty essential kinds of atoms. Mostly built, as a matter of fact, of just six kinds of atoms–sulfur, phosphorus, carbon, oxygen, hydrogen and nitrogen. Some remember these important six by the mnemonic device, S. P. COHN.

the cycling of elements

All of the life-important atoms circulate around in the ecosystem. The ecologist can trace their flow



into and out of the air, water and earth. Into and out of the producer plants, the consumer animals and the decomposer microorganisms. In the air, water and soil, the atoms and the relatively simple compounds they make–things like carbon dioxide, water, inorganic acids, bases and salts–are called the abiotic level of the ecosystem.

abiotic level of biosphere

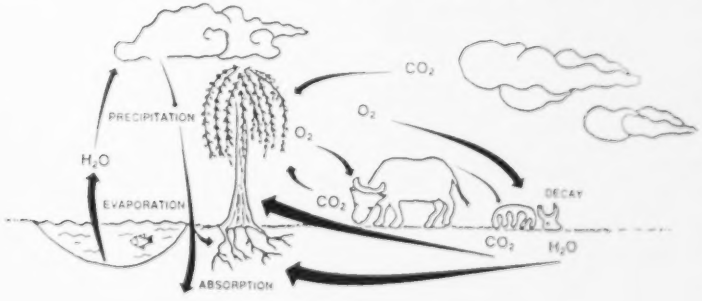
Producer plants take up abiotic chemicals and use them as raw materials for building a bewildering variety of much more complicated chemicals. Chemicals like sugars, starches, proteins, oils, enzymes, nucleic acids and the literally billions of kinds of organic chemicals that go to make up the leaf, the stem, the seed and the fruit.

consumer chemicals

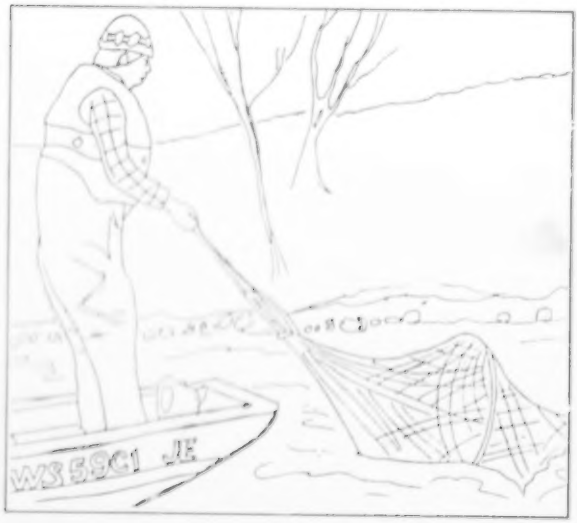
These plant-produced chemicals are then used by the consumer animals to make still more chemicals. Chemicals just as complex and even more incredibly organized together to make the functioning hawk, mink, frog and human being.

need for decomposers in recycling

Which chemicals are then broken apart once again, recycled back into the abiotic from which they came. This recycling is the job of the decom-



posers in every ecosystem. These broad patterns of matter and energy cycling in the ecosystem provide a basic framework which ecologists can use in trying to understand the fascinating complexities of specific environments.



ecosystem problems from many angles

In addition, ecologists have found other new ways to study ecosystems. They investigate things like population size, structure and growth; limiting factors and succession patterns; predator-prey and parasite-host relationships; species competition; ecological indicators; and more.

different kinds of ecosystems

Some ecologists specialize in the study of freshwater ecosystems like Silver Springs, Florida. Others specialize in marine ecology, tropical rain forests, northern hardwood forests, prairies, agricultural regions, mountain slopes, deserts, bogs and just about any place where life exists.

space ecology

The field is limited only by the limits of the earth itself. And as a matter of fact, not by the earth either. Some ecologists are already beginning to plan and study a new field–space ecology.

environmental problems

Probably the most important applications of ecology today are to the critical problems of human life aboard our spaceship earth. And here come the questions that make headlines. When you get to specific cases like acid rain, the greenhouse effect, oil spills, nuclear wastes, pesticide residues, etc. the answers are not easy. This is partly because we just don't know enough yet. And partly because the answers often depend as much on what people value as what people know.

wilderness or jobs?

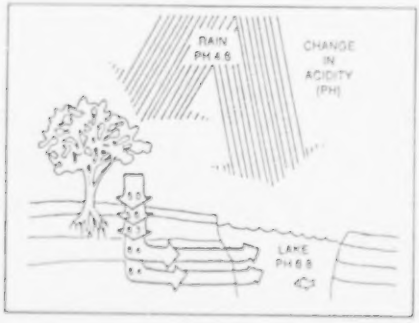
For instance. Ecologists and naturalists can offer many reasons why a given ecosystem should be preserved as a wilderness. Why no roads should be built, and all but the most determined and hardy visitors kept out. In a democratic society, however, these reasons must be balanced against equally cogent ones that others may put forward for developing these same lands. For using the natural resources therein to create jobs, increase wealth and overcome poverty.

scientific evidence

In some controversial cases, ecologists can be more definitive about the facts. At the very least they can present the scientific evidence linking such and such an event. And they can tell us to what degree we can have confidence in those links.

acid rain

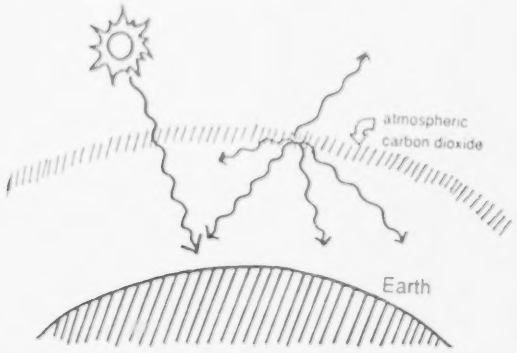
Some ecologists, for instance, are spending a great deal of time right now studying the damage that acid rain may cause in forest and fresh water ecosystems in this country and abroad. Others study the possible effects of toxic waste leakage from old landfills. Or the ecological consequences of cutting tropical rain



forests in Brazil or reducing the flow of water in the Colorado River. Others study ways to control pests like the gypsy moth or the Mediterranean fruit fly. Still others try to trace the effects on ecosystems from oil spills like that at Valdez, Alaska in 1989. Or from nuclear power accidents like those at Three Mile Island in Pennsylvania or at Chernobyl in the USSR.

studies of biosphere problems

Larger scale studies of the entire earth biosphere are also being made today, using very large computers. The greenhouse effect, depletion of the ozone layer, nuclear winter, toxic wastes in the ocean are just a few of the most important.



knowledge incomplete

Unfortunately our knowledge of ecosystems, small or large, is still very incomplete. In addition, there are so many variables that even the largest computer cannot take them all into account. Despite these handicaps, ecologists are making progress and providing important insights into the earth's amazing life cycles.

a new ethic for earth citizens

And however the approach might vary, ecologists and naturalists and all concerned and intelligent citizens can agree that a new ethic about the earth is slowly taking root. An ethic shared by a growing majority of spaceship earth's passengers and crew.

spaceship earth

Ecology means "living at home," and we know now that our home is this blue-white spaceship we call earth. As the politican Adlai Stevenson once said, "We travel together, passengers on a little space ship, dependent on its vulnerable supplies of air and soil ... preserved from annihilation only by the care, the work, and I will say the love, we give our fragile craft."

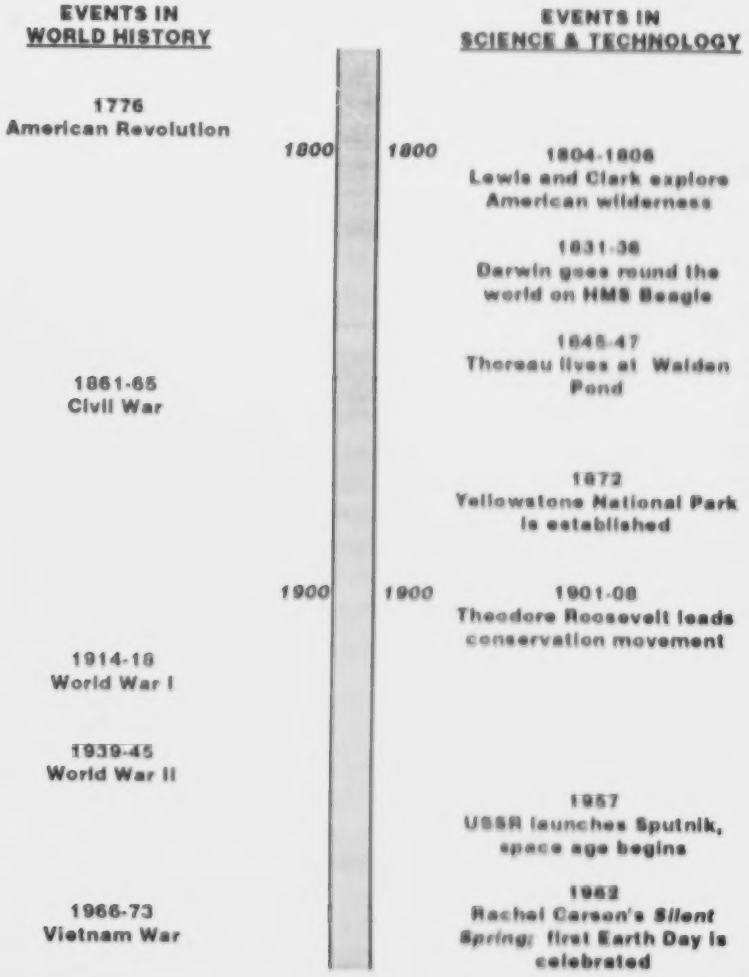
environment and me

The scientist, engineer and poet Buckminster Fuller had another way of putting it.

Environment, to each must be,
all that is that isn't me.
Universe in turn will be
all that isn't me and me.

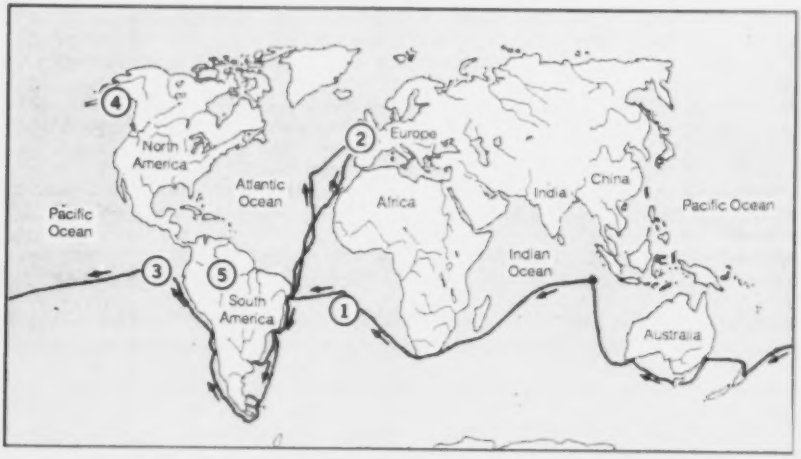
TIME ...

To understand the world of today it helps to know something about the world of yesterday. Kings and queens, wars and famines, presidents and paupers have all played a part. But more important than any of these in changing the past world into the world of today has been science and technology. The time line below will help you place important events and people in historical time.



SPACE ...

There is a saying, "If you don't know where you are going, any road will get you there." One of the important parts of knowing where you are going is a knowledge of geography. The map below will help you to locate the important events and people discussed in this book.



1. Route of HMS Beagle — From 1831 to 1836 Charles Darwin sailed around the world on HMS Beagle as an unpaid naturalist. His explorations eventually led to construction of a new theory of evolution by natural selection.

2. England — Site of Darwin's country home near London where he wrote *On the Origin of Species by Means of Natural Selection.*

3. Galapagos Islands — One of the most productive stops on Darwin's voyage. Many examples of the effects of isolation on the evolution of species.

4. Valdez, Alaska — Site of a large oil spill in 1989 when the *Exxon Valdez* ran aground. Clean-up still in progress.

5. Brazilian rain-forest — The world's largest tropical rain forest. Threatened by agricultural developments.

6. Route of Lewis and Clark — In 1804 President Thomas Jefferson sent a party of explorers headed by Meriwether Lewis and William Clark to explore the vast American wilderness west of the Mississippi.

7. Concord, Massachusetts — Site of Walden Pond where Henry David Thoreau lived in a cabin he built himself and wrote his classic book, *Walden*.

8. Silver Springs, Florida — A fresh water pond studied by Howard Odum and his associates in 1957 in one of the pioneering ecological studies. Is also a well-known tourist attraction today.

9. Yellowstone National Park — The first of America's national parks, established in 1872. Visited by over two million people every summer. Experienced severe forest fires in 1988.

10. Wisconsin River — In a cabin on the Wisconsin River Aldo Leopold wrote his book, *Sand County Almanac*.

SPIRIT...

Time and space are meaningless without spirit. Spirit is the part in each of us that understands. The part that sees connections between words and things–connections that surprise and make sense. Study the key words, concepts and ideas below so that you can understand how time, space and spirit have worked in the past–and are working today.

abiotic — The non-living part of the biosphere. (p. 3, 17-18)

acid rain — Rain that carries sulfur and nitrogen oxides dissolved in it and can cause serious damage to some ecosystems. (p. 20-21)

biology — The science that studies living things. (p. 13)

biosphere — The very thin outermost layer of planet Earth where life flourishes. (p. 11, 15, 21-22)

consumer — A living organism in the biosphere that uses stored energy made by plants. (p. 15-16)

Darwin, Charles — An English naturalist who proposed a theory of evolution by natural selection. (p. 5-7)

decomposer — A living organism in the biosphere that breaks down plant and animal wastes. (p.16-17)

ecologist — A scientist who specializes in the study of living things in their environment.

ecology — The science of living things in their environment.

ecosystem — Living things and the environment in which they live considered together as a single system. (p. 3, 8, 16, 19)

energy — The ability to do work. One of the major factors ecologists study in ecosystems. (p. 13-15)

food chain — A sequence of relationships among living things that describes what eats what. (p. 3, 14-16)

greenhouse effect — A gradual warming of earth's climate caused by excessive carbon dioxide which reflects heat

	back to earth instead of letting it escape into space. (p. 20-21)
natural selection	The process in which nature decides which organisms are best fit to survive and reproduce. First proposed by Charles Darwin in *On the Origin of Species by Means of Natural Selection.* (p. 6-7)
naturalist	A person with a serious interest in the study of plants and animals in nature. (p. 3-4, 9, 21)
niche	A particular place in an ecosystem where a particular species makes its living and home. (p. 5)
parasite	A living organism that gets its life energy from another organism (the host), harming it in the process. (p. 19)
photosynthesis	The process in which green plants make food using the energy of sunlight. (p. 15)
predator	An animal that gets its food by killing other animals (the prey). (p. 19)
producer	A living organism that uses non-living energy sources to power its own life. With a few exceptions, producers are the green plants of the world. (p. 15-17)
quantitative	Measured and expressed in numbers. (p. 8-9)
recycling	In ecosystems the way all elements needed for life are used over and over again as they move through the abiotic-producer-consumer-decomposer cycle. (p. 17-18)
Roosevelt, Theodore	President of the United States (1901-1910) and leader of one of the first conservation movements in this country. (p. 10)
species	A particular kind of living thing that can reproduce with other members of its own kind. (p. 7, 19)
struggle for existence	In nature the competition for food, space and other living needs. (p. 6)

survival of fittest — In nature the result of evolution where the species most able to survive do. (p. 6-7)

thermodynamics, laws of — Two laws of energy. The first law of thermodynamics says that energy cannot be created or destroyed. The second law of thermodynamics says that in every energy change there is a loss to random heat. (p. 13-15)

Thoreau, Henry David — An American writer and naturalist of the mid-nineteenth century who wrote a classic book, *Walden*. (p.1-4, 12)

Walden — Name of book by Henry David Thoreau which he named after a pond near Concord, Massachusetts. (p. 1-4, 12)

wilderness — A natural area undisturbed by human activities. (p. 10, 20)

In addition to the above, *Ecosystems* also teaches about other important people, places, things and ideas. Often you can figure out the meaning of a new term by seeing how it is used in context. Make sure you know the meaning of the following (for help, check the pages listed in this Learning Power Book, as well as your dictionary and encyclopedia):

Audubon, John Jacob (p. 10); **Bacon, Francis** (p. 4); **Brazil** (p. 21); **Buddhism** (p. 4); **Burroughs, John** (p. 10); **Carson, Rachel** (p. 11); **Chernobyl** (p. 21); **Christianity** (p. 4); **conservation** (p. 10); **Hinduism** (p. 4); **HMS Beagle** (p. 6); **Jefferson, Thomas** (p. 10); **kilocalories** p. 8); **Leopold, Aldo** (p. 10-11); **Lewis & Clark** (p. 10); **Manifest Destiny** (p. 10); **Odum, Howard** (p. 1-4, 8-9); **ozone** (p. 21); **pesticides** (p. 20); **physicist** (p. 13); **spaceship earth** (p. 7, 20); **S.P. COHN** (p. 17); **Taoism** (p. 4); **Three-Mile Island** (p. 21); **toxic wastes** (p. 11, 20-21).

STUDY SUGGESTIONS ...

1. Study the natural ecosystems closest to your home or school. In what ways have these ecosystems changed in the last ten years? The last fifty years? How are they different from the days before Europeans came to this country? Which were healthiest for human beings?

2. Brazil's tropical rain forests are rich in a great variety of plant and animal life. This diversity and richness is threatened now by ever increasing deforestation and attempts to turn areas to agricultural uses. Some Brazilians argue that economic development must take priority over conservation. Investigate the arguments of both conservationists and developers. Debate the issues.

3. A growing political movement called the "Greens" began in West Germany and has since spread to other countries, including the United States. Investigate what the movement stands for, what influence it has had in the past and is likely to have in the future.

4. Read (or re-read) Thoreau's *Walden*. If Thoreau were writing today it is pretty clear what positions he would take on issues like wilderness, environment, etc. What position would he take on other current national and international issues like: drug traffic, social welfare laws, wealth and poverty, public education, civil rights and civil liberties. What positions would Charles Darwin take on these same issues?

5. For an eye-opening view of how early Americans viewed the wilderness read the journals of Lewis and Clark. They led the first expedition to explore the vast region of the American West from the Mississippi to the Pacific Ocean from 1804 to 1806.

6. One of the most controversial of modern issues is that of pesticides and insecticides getting into our food supply. Investigate the claims of various groups and individuals on this issue. Note especially the work of Dr. Bruce Ames of University of California-Berkeley. Also review the book by Edith Efron. See bibliography.

7. On March 24, 1989 an oil tanker, *Exxon Valdez*, ran aground spilling eleven million gallons of crude oil in Alaska coastal waters. Since then there has been a great deal of controversy among ecologists, politicians, economists and citizens. Follow this story and others like it in the current press and magazines. Research and debate.

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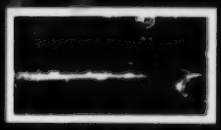

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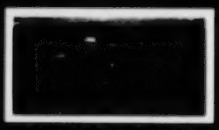

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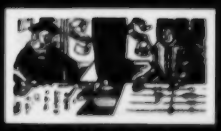

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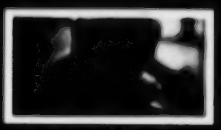

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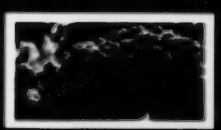

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